Torsional and cross-coupled vibration

The rotor of a machine generates vibration in the directions in which it has freedom to move. Vibration in the direction of the rotor axis is *axial* vibration, and vibration in the direction of the rotor radius (at right angles to the rotor axis) is *radial* (or *lateral*) vibration. Vibration in the direction that the shaft turns is *torsional* vibration.

Torsional vibration is continuous, oscillatory angular motion. It is the result of variable torque along the rotor; if torque is constant, the rotor experiences no torsional vibration. Torsional vibration most often appears when a prime mover, such as a motor, drives a compressor, and the speed or compressor load are not constant. Some of the most common sources are motor pulsations, unbalanced electrical forces and fluctuating load (torque) requirements. Although torsional vibration problems may seem more complex than radial vibration problems, the two types are related, and the same basic formulas solve both types of problems. See Table 1.

Vibration in one direction can influence vibration in another direction, through cross-coupling. Torsional and radial vibration may not be cross-coupled because a machine's torsional natural frequencies are usually in a much higher range than those of radial modes. Typical forcing functions in rotating machines (except those with gear transmissions and those with variable speed drivers) usually do not excite high torsional vibrations. However, if torsional natural frequencies are lower, and in the machine's operating speed range, cross-coupling can occur and result in radial vibration.

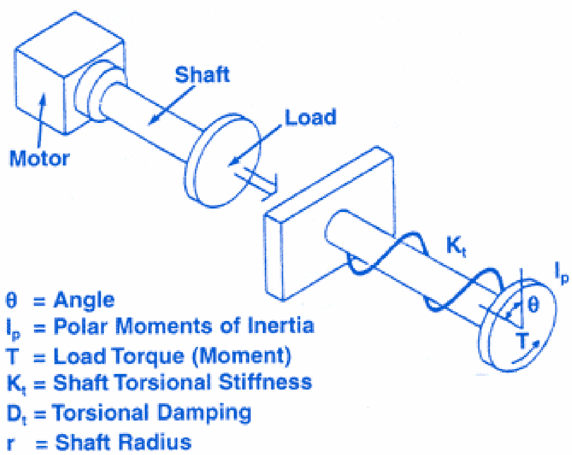

Figure 1
Power transmission diagram. In this model, the motor provides constant rotative speed at a steady state condition.

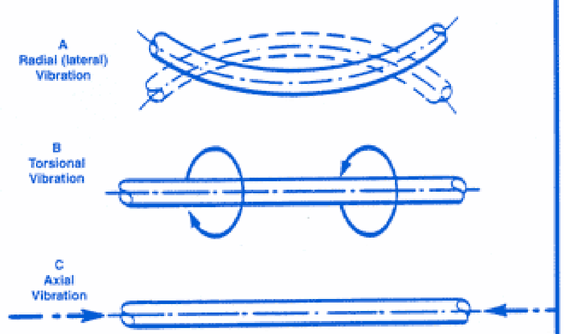

Figure 2
Radial, torsional and axial shaft vibration.

Element	Lateral Vibration	Torsional Vibration
Mass/Inertia	M = kg (lb•s²/in)	I_p = Mr² = kg•m² (lb•s²•in)
Spring	K = N/m (lb/in)	K_t = N•m/rad (lb•ft/rad)
Damping	D = N•s/m (lb•s/in)	D_t = N•m•s/rad (lb•ft•s/rad)
Force/Torque	F = N (lb)	T = N•m (lb•ft)
Acceleration	a = mm/s² (in/s²)	a/r = rad/s²
Velocity	v = mm/s (in/s)	v/r = rad/s
Displacement	d = mm (in)	d/r = rad

Table 1